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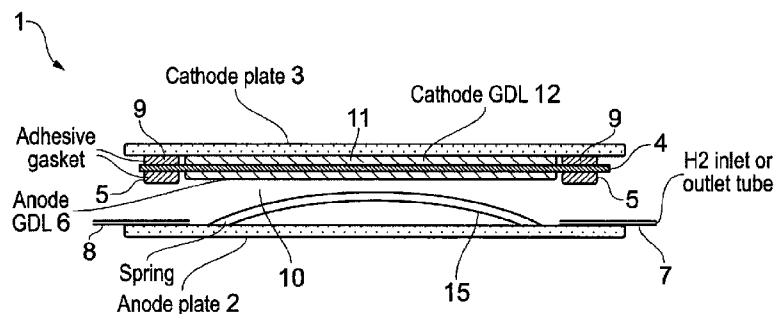
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(54) **Title:** FUEL CELL EXPANSION MEMBER TO BIAS GAS DIFFUSION LAYER

**FIG. 1**

(57) **Abstract:** A fuel cell comprises a first electrode plate and a second electrode plate and a membrane- electrode assembly disposed between the first and second electrode plates. The electrode plates and the MEA together define first and second fluid flow volumes for conveying fluids respectively to first and second active areas on first and second sides of the MEA. A diffusion layer is disposed between the MEA and the first electrode plate within the first fluid flow volume. An expansion member is disposed within the first fluid flow volume and between the diffusion layer and the first electrode plate. The expansion member is configured to expand within the first fluid flow volume to bias the diffusion layer into close contact with the MEA under varying degrees of expansion of the first fluid flow volume.

FUEL CELL EXPANSION MEMBER TO BIAS GAS DIFFUSION LAYER

The present invention relates to methods and apparatus suitable for assembling an electrochemical fuel cell or fuel cell stack.

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Fuel cell stacks comprise a series of individual fuel cells built up layer by layer into a stack arrangement. Each cell may include various layered components such as a polymer electrolyte membrane, gas diffusion layers, anode and cathode fluid flow plates and various sealing gaskets for maintaining fluid tightness and providing fluid fuel and oxidant distribution to the active surfaces of the membrane. At each end face of the stack, a pair of end plates coupled together by tie rods is conventionally used to hold the stack together and maintain compression on the cells in the stack.

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It is important that pressure applied by the end plates to the end faces of the fuel cell stack is sufficiently uniform across the surfaces of the stack that individual components of the stack are maintained in proper compressive relationship with one another.

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Uniform pressure may be maintained by providing substantial and robust end plates capable of maintaining sufficient pressure across the entire surfaces of the ends of the stack. This results in large and heavy end plates to ensure that they are sufficiently robust that they will not significantly distort under the requisite pressures and will not apply compression forces unevenly. Use of large and heavy end plates results in heavier and larger fuel cell stacks than is desirable. An alternative approach is to use lighter weight end plates but provide an additional mechanism for mitigating the effects of end plate structure distortion when compressive forces are applied.

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An approach described in US 6200698 is to use an end plate assembly having a sealed bladder containing a two-phase fluid operable to maintain, over an extended period of time, a generally uniform distributed stack compression pressure. The use of a two phase fluid results in the bladder being pressurized even if gas slowly leaks from the bladder.

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Another approach is described in US 6258475 which uses an end plate assembly having a silicone oil filled liquid chamber sandwiched between a back-up plate and an end plate. The chamber is sealed at pressure.

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These approaches may be said to increase the complexity and cost of end plate assemblies and may not be optimal for all fuel cell designs.

5 It is an object of the present invention to provide an alternative way of ensuring that individual components of a fuel cell or fuel cell stack are maintained in proper compressive relationship with one another.

According to one aspect, the present invention provides a fuel cell comprising:

- 10 a first electrode plate;
- a second electrode plate;
- a membrane-electrode assembly disposed between the first and second electrode plates, the electrode plates and the MEA together defining first and second fluid flow volumes for conveying fluids respectively to first and second active areas on first and second sides of the MEA;
- 15 a diffusion layer disposed between the MEA and the first electrode plate within the first fluid flow volume; and
- an expansion member disposed within the first fluid flow volume and between the diffusion layer and the first electrode plate, the expansion member configured to expand within the first fluid flow volume to bias the diffusion layer into close contact with the MEA
- 20 under varying degrees of expansion of the first fluid flow volume.

The expansion member may comprise a spring element. The expansion member may comprise a leaf spring. The expansion member may comprise a compressible foam or sponge material. The expansion member may comprise an electrically conductive

25 material. The expansion member may be capable of expanding to maintain contact with the diffusion layer and the first electrode plate under an expansion of the thickness of the fluid flow volume by at least a factor of two. The first electrode plate may be an anode plate, the second electrode plate may be a cathode plate, the first fluid flow volume may be an anode fluid flow volume, and the second fluid flow volume may be a cathode fluid

30 flow volume. The fuel cell may further include a second diffusion layer disposed between the MEA and the second electrode plate within the second fluid flow volume, and a second expansion member disposed within the second fluid flow volume, the second expansion member configured to expand within the second fluid flow volume to bias the second diffusion layer into close contact with the MEA under varying degrees of expansion of the

35 second fluid flow volume. The electrode plates, MEA and expansion member may be

flexible and / or non-planar. The electrode plates and the MEA may be coupled together with a perimeter gasket and adhesive.

5 The present invention also provides a fuel cell assembly comprising a stack of fuel cells as defined above.

According to another aspect, the present invention provides a method of operating a fuel cell comprising:

10 providing a first electrode plate, a second electrode plate and a membrane-electrode assembly disposed between the first and second electrode plates, the electrode plates and the MEA together defining first and second fluid flow volumes for conveying fluids respectively to first and second active areas on first and second sides of the MEA;

disposing a diffusion layer between the MEA and the first electrode plate within the first fluid flow volume;

15 disposing an expansion member within the first fluid flow volume and between the diffusion layer and the first electrode plate;

pressurising the first fluid flow volume with reactant fluid thereby causing the first fluid flow volume to expand by distortion of the first electrode plate, the expansion member expanding within the expanded first fluid flow volume to maintain a bias of the diffusion layer into close contact with the MEA.
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The method may further include varying the pressure of reactant fluid in the first fluid flow volume thereby generating varying degrees of expansion of the first fluid flow volume, the expansion member maintaining the bias of the diffusion layer in close contact with the MEA
25 for the varying degrees of expansion.

Embodiments of the present invention will now be described by way of example and with reference to the accompanying drawings in which:

30 Figure 1 shows a schematic cross-sectional view of a fuel cell in partly assembled condition;

Figure 2 shows a schematic cross-sectional view of the fuel cell of figure 1 in assembled condition;

Figure 3 shows a schematic cross-sectional view of an alternative design of fuel cell in partly assembled condition;

Figure 4 shows a schematic cross-sectional view of the fuel cell of figure 3 in assembled condition.

In the fuel cell assembly to be described, there is proposed an alternative approach to solely relying on end plates to compress a fuel cell or fuel cell stack, with or without features to prevent or mitigate end plate bending. An expansion member is inserted into an anode fluid flow chamber. This expansion member is capable of ensuring that other components within the fuel cell assembly are maintained in a suitable compressive relationship even when, in use, the fuel cell itself distorts under an applied pressure of anode gas, such as hydrogen.

Figure 1 shows a fuel cell assembly 1 comprising an anode plate 2 and a cathode plate 3 which confine a membrane-electrode assembly (MEA) 4. The anode plate 2 and the MEA 4 together define an anode fluid flow volume 10, bounded by a perimeter gasket 5, which contains an anode gas diffusion layer (GDL) 6. An anode fluid supply conduit 7 extends from outside the fuel cell assembly 1 to the anode fluid flow volume 10. An anode exhaust conduit (or purge conduit) 8 may extend from the anode fluid flow volume 10 to outside the fuel cell assembly 1. The cathode plate 3 and the MEA 4 together define a cathode fluid flow volume 11 bounded by a perimeter gasket 9 which contains a cathode gas diffusion layer (GDL) 12. A cathode fluid supply conduit (not shown) extends from outside the fuel cell assembly 1 to the cathode fluid flow volume 11. A cathode exhaust conduit (not shown) extends from the cathode fluid flow volume 11 to outside the fuel cell assembly 1.

Within the anode fluid flow volume 10 is an expansion member in the form of a spring 15. The spring preferably comprises a leaf spring, e.g. an arc-shaped length of spring material such as beryllium-copper. The spring may be any suitable shape, and preferably substantially fills an area of the anode fluid flow volume 10 sufficient to be able to bias the anode gas diffusion layer 6 against the MEA 4 over a substantial portion of the area of the GDL 6. This can be seen in figure 2 which shows the fuel cell assembly 1 fully assembled, and the spring 15 compressed. The leaf spring may be arc-shaped in two dimensions, i.e. to create a concave / convex element. The leaf spring could be formed of multiple layers to increase the strength of spring.

As shown in figure 2, when the fuel cell is assembled, a perimeter bead of glue 14 or other bonding material may be used to further seal the perimeter of the fuel cell assembly and bond the anode plate 2, cathode plate 3, gaskets 5, 9 and MEA 4 together. For individual fuel cells, or for small stacks, the bonding material 14 may be sufficient to avoid the need for compression end plates, as discussed further below.

In use, when the anode is pressurised with anode fluid (e.g. hydrogen), the pressure of the anode fluid may cause at least the anode plate 2 to expand or bulge. In prior art designs, the anode pressure may be resisted by rigid end plates to prevent bulging. Bulging or expansion of the anode fluid flow volume 10 could ordinarily cause the anode GDL 6 to no longer be in close contact and compressive relationship with the MEA 4, thereby compromising the performance of the fuel cell. In the design of figures 1 and 2, however, any bulging of the anode plate of the fuel cell assembly 1 is compensated for by expansion of the expansion member, i.e. spring 15. Because the spring 15 resides within the anode fluid flow volume 10, there is little or no pressure differential across it and with very little expansion force the expansion member 15 can expand in the fuel cell thickness direction and continue to bias the anode GDL 6 against the MEA 4, and thereby also against the cathode GDL 12 and the cathode plate 3. In this way, critical elements in the electrically conductive path are maintained in compressive relationship.

The spring 15 is preferably electrically conductive, or coated in an electrically conductive material, and allows current to flow between the GDL 6 and the anode plate 2, either through the spring 15 or along its conductive surface. Where a beryllium-copper material is used for the spring 15, it may be preferable to plate the spring with tin to avoid possible copper poisoning of catalyst material on / in the MEA 4.

With this expansion element fitted inside the anode fluid flow volume 10, it is possible to construct the fuel cell using much thinner and/or lighter and/or weaker endplates, or rely solely on the anode plate 2 and cathode plate 3 as end plates. If the end plates deform due to the pressurised anode fluid in the anode fluid flow volume, the expansion member internal to the fluid flow volume will take up any gap created and ensure the conductive elements within the fuel cell (anode current collector, anode GDL, MEA, cathode GDL, cathode current collector) remain in good electrical contact with one another and the fuel cell continues to function properly.

An alternative arrangement of fuel cell assembly 21 is shown in figures 3 and 4. In this arrangement, the fuel cell assembly 21 comprises an anode plate 22, a cathode plate 23, a membrane-electrode assembly (MEA) 24 defining an anode fluid flow volume 30 and cathode fluid flow volume 31 bounded by perimeter gaskets 25 and 29 similar to that described in connection with figures 1 and 2. The anode fluid flow volume 30 contains an anode gas diffusion layer (GDL) 26 and an anode fluid supply conduit 27 and anode exhaust conduit 28 extend from outside the fuel cell assembly 21 to the anode fluid flow volume 30. The cathode fluid flow volume 31 contains a cathode gas diffusion layer (GDL) 32 and a cathode fluid supply conduit (not shown) and a cathode exhaust conduit (not shown) extend from outside the fuel cell assembly 21 to the cathode fluid flow volume 31, similar to figures 1 and 2.

Within the anode fluid flow volume 30 is an expansion member in the form of a compressible foam or sponge material layer 35. The expansion member 35 may be any suitable material capable of expanding to fill any increase in the volume of the anode fluid flow volume 30 under pressurisation with anode fluid, e.g. hydrogen. The expansion member 35 is preferably an electrically conductive foam or sponge material. Alternatively, the expansion member could be an electrically non-conductive foam or sponge material (or material of low electrical conductivity), but with an electrically conductive coating or wrapping 36 to maintain electrical continuity between the anode plate 22 and the GDL 26. A shim may be inserted between the foam or sponge material layer and the electrically conductive coating or wrapping to create a dome shape which may more evenly distribute compression. The sponge material could be silicone sponge wrapped in a thin film or plate such as flexible PCB material or thin metal plate or foil. The foam or sponge material could be open cell or closed cell.

The expansion member 35 is preferably porous to allow easy flow or diffusion of anode fluid therethrough. If the expansion member comprises an electrically conductive wrapping, this wrapping may also be porous, e.g. a mesh.

The expansion member 35 preferably substantially fills an active area of the anode fluid flow volume 30 sufficient to be able to bias the anode gas diffusion layer 26 against the MEA 24 over a substantial portion of the GDL 26, as can readily be seen in figure 4 which shows the fuel cell assembly 21 fully assembled, and the foam or sponge layer 35

compressed. The expansion member 35 (or 15) preferably extends at least over an area that could be affected by bulging of the anode plate 22 (or 2).

5 As shown in figure 4, when the fuel cell 21 is assembled, a perimeter bead of glue 34 or other bonding material may be used to further seal the perimeter of the fuel cell assembly and bond the anode plate 22, cathode plate 23, gaskets 25, 29 and MEA 24 together. For individual fuel cells, or for small stacks, the bonding material 34 may be sufficient to avoid the need for compression end plates.

10 Similar to the operation of the fuel cell assembly 1 of figures 1 and 2, in use the anode is pressurised with anode fluid (e.g. hydrogen), via the conduit 27, and the pressure of the anode fluid may cause at least the anode plate 22 to expand or bulge. Any bulging of the anode plate is compensated for by expansion of the foam or sponge material 35. Because the foam or sponge material 35 resides within the anode fluid flow volume 30, there is little
15 or no pressure differential across it and with very little expansion force, the expansion member 35 can expand in the fuel cell thickness direction and continue to bias the anode GDL 26 against the MEA 24, and thereby also against the cathode GDL 32 and the cathode plate 33.

20 With this expansion element fitted inside the anode fluid flow volume, it is possible to construct the fuel cell using much thinner and/or lighter and/or weaker endplates, or rely solely on the anode plate 22 and cathode plate 23 as end plates. If the end plates deform due to the pressurised anode fluid in the anode fluid flow volume, the expansion member internal to the fluid flow volume will take up any gap created and ensure the conductive
25 elements within the fuel cell remain in good electrical contact with one another and the fuel cell continues to function properly.

A number of variations and modifications may readily be applied to the fuel cell assemblies described above.

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An expansion member such as the spring 15 or the foam / sponge material layer 35 can also or instead be provided on the cathode side of the fuel cell assembly. For example, an expansion member could be disposed in the cathode fluid flow volume 11, 31 between the cathode plate 3, 23 and the cathode GDL 12, 32. This could serve to compensate for

any expansion in the cathode fluid flow volume 11, 31 as a result of pressurisation of the cathode with cathode fluid, e.g. air or other oxidant.

5 The fuel cell assemblies 1, 21 can be manufactured as single fuel cell assemblies or as part of a stack of fuel cells, e.g. in a series-connected stack configuration. Not all fuel cells in such a stack need necessarily have the expansion member. For example, expansion members might be incorporated into selected cells in the stack. The fuel cell assemblies could also form part of a larger area array of series- or parallel-connected fuel cells, e.g. in a planar array.

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Either or both the anode plate 2, 22 and the cathode plate 3, 23 could form an end plate of a single cell or multi-cell stack arrangement, with the expansion member providing compensation for any weakness in the plates in their ability to resist deformation under pressurisation of the fuel cell. This does not preclude also using end plates to provide a
15 degree of compression of the fuel cell, or of fuel cells in a stack.

The expansion member exemplified by spring 15 and foam or sponge material 35 may be any suitable material or element which is capable of expanding to maintain contact with the diffusion layer and the electrode plate (e.g. anode plate or cathode plate) with which it
20 is associated, under an expansion of the thickness of the fluid flow volume 10, 11, 30, 31 caused, for example, by pressurisation of the fuel cell by anode or cathode fluids. In this respect, the expansion member may be configured to expand to maintain such contact when the thickness of the fluid flow volume increases by a factor of at least two, more preferably by a factor of four or eight or several tens or more.

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In one example, where plastic end plates of 1.6 mm thick FR4 epoxy material are used, an expected gap created between the GDL and the MEA upon pressurisation of the anode with anode fluid, and consequent distortion or deformation of the end plates, is of the order of a few tens of microns. The expansion member is therefore configured to expand by at
30 least this amount. A spring element formed from a 300 micron thick steel strip can be bent to form a spring with, e.g. up to 10 mm of travel, providing a factor of over 30 times expansion.

The fuel cell assemblies as exemplified above may be fabricated as planar fuel cells as shown, or as non-planar fuel cells which can follow a curved surface, or as flexible fuel cells capable of being applied to or mounted on curved substrates for example.

- 5 Other embodiments are intentionally within the scope of the accompanying claims.

CLAIMS

1. A fuel cell comprising:
a first electrode plate;
5 a second electrode plate;
a membrane-electrode assembly disposed between the first and second electrode plates, the electrode plates and the MEA together defining first and second fluid flow volumes for conveying fluids respectively to first and second active areas on first and second sides of the MEA;
10 a diffusion layer disposed between the MEA and the first electrode plate within the first fluid flow volume; and
an expansion member disposed within the first fluid flow volume and between the diffusion layer and the first electrode plate, the expansion member configured to expand within the first fluid flow volume to bias the diffusion layer into close contact with the MEA
15 under varying degrees of expansion of the first fluid flow volume.
2. The fuel cell of claim 1 in which the expansion member comprises a spring element.
3. The fuel cell of claim 2 in which the expansion member comprises a leaf spring.
20
4. The fuel cell of claim 1 in which the expansion member comprises a compressible foam or sponge material.
5. The fuel cell of claim 1 in which the expansion member comprises an electrically
25 conductive material.
6. The fuel cell of claim 1 in which the expansion member is capable of expanding to maintain contact with the diffusion layer and the first electrode plate under an expansion of the thickness of the fluid flow volume by at least a factor of two.
30
7. The fuel cell of claim 1 in which the first electrode plate is an anode plate, the second electrode plate is a cathode plate, the first fluid flow volume is an anode fluid flow volume, and the second fluid flow volume is a cathode fluid flow volume.

8. The fuel cell of claim 1 further including a second diffusion layer disposed between the MEA and the second electrode plate within the second fluid flow volume, and a second expansion member disposed within the second fluid flow volume, the second expansion member configured to expand within the second fluid flow volume to bias the second diffusion layer into close contact with the MEA under varying degrees of expansion of the second fluid flow volume.

9. The fuel cell of claim 1 in which the electrode plates, MEA and expansion member are flexible and / or non-planar.

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10. The fuel cell of claim 1 in which the electrode plates and the MEA are coupled together with a perimeter gasket and adhesive.

11. A fuel cell assembly comprising a stack of fuel cells each according to any one of claims 1 to 10.

12. A method of operating a fuel cell comprising:

providing a first electrode plate, a second electrode plate and a membrane-electrode assembly disposed between the first and second electrode plates, the electrode plates and the MEA together defining first and second fluid flow volumes for conveying fluids respectively to first and second active areas on first and second sides of the MEA;

disposing a diffusion layer between the MEA and the first electrode plate within the first fluid flow volume;

disposing an expansion member within the first fluid flow volume and between the diffusion layer and the first electrode plate;

pressurising the first fluid flow volume with reactant fluid thereby causing the first fluid flow volume to expand by distortion of the first electrode plate, the expansion member expanding within the expanded first fluid flow volume to maintain a bias of the diffusion layer into close contact with the MEA.

30

13. The method of claim 12 further including varying the pressure of reactant fluid in the first fluid flow volume thereby generating varying degrees of expansion of the first fluid flow volume, the expansion member maintaining the bias of the diffusion layer in close contact with the MEA for the varying degrees of expansion.

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14. Apparatus substantially as described herein with reference to the accompanying drawings.

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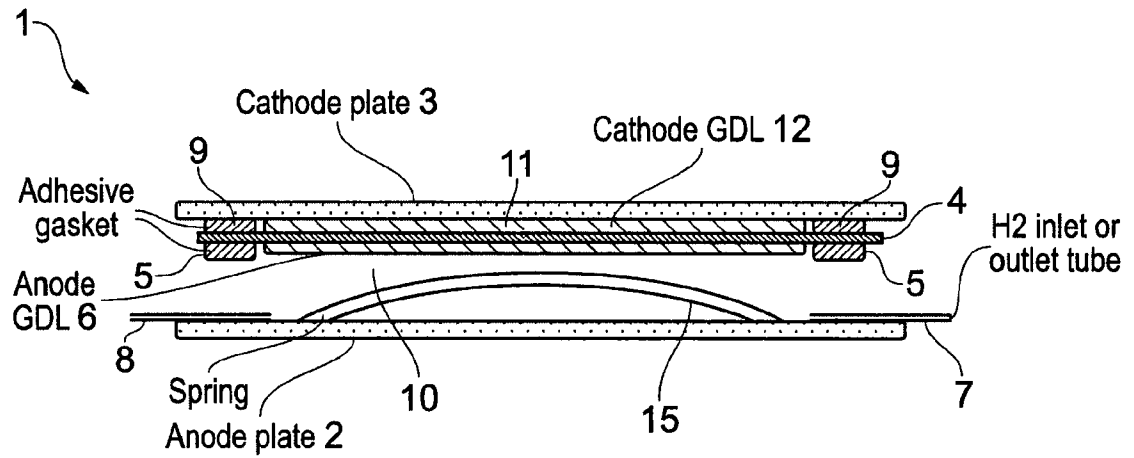


FIG. 1

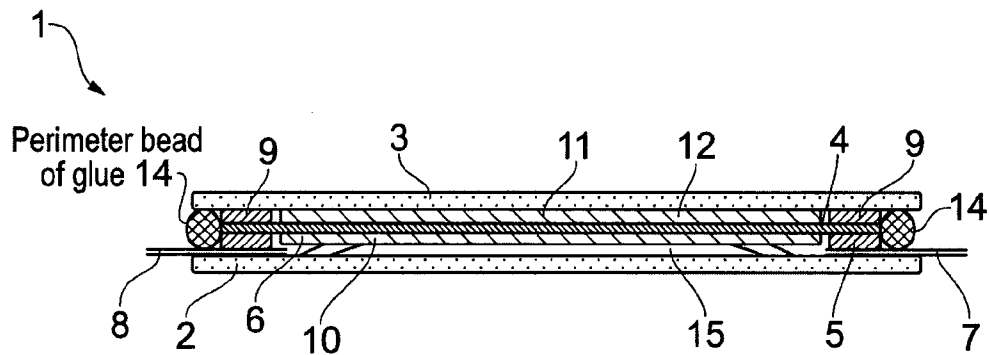


FIG. 2

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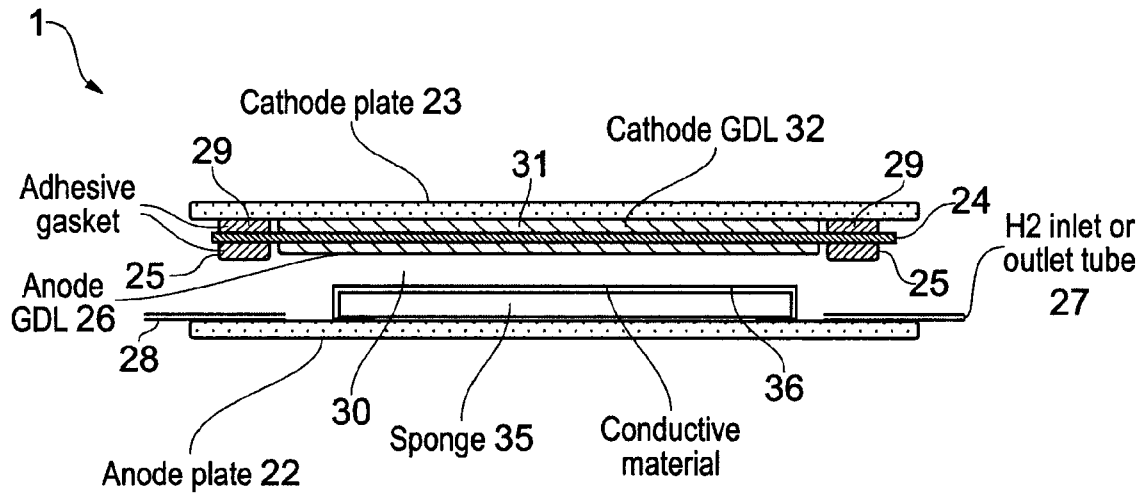


FIG. 3

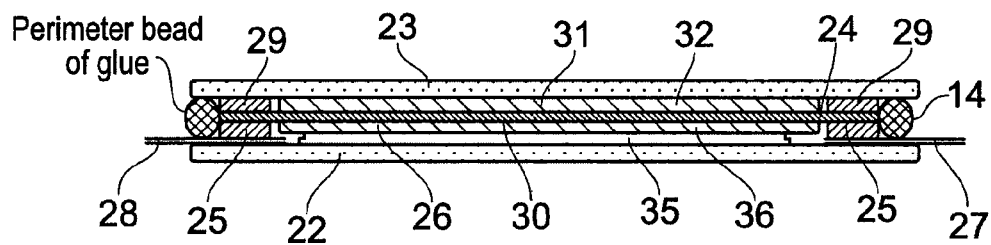


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2015/052485

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01M8/10 H01M8/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	WO 2014/010382 A1 (NISSAN MOTOR [JP]) 16 January 2014 (2014-01-16) paragraphs [0009] - [0013], [0019] - [0027]; figure 1	1,4,11, 12
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☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

26 November 2015

Date of mailing of the international search report

03/12/2015

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2015/052485

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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